Fast Reactor Spent Nuclear Fuel Recycling Facility NEPA Data Input Report

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Summary of Changes

Issue Date	Revision	Description
04/25/07	A	Initial Draft
6/29/07	B	Incorporation of Comments and Data
07/17/07	0	Initial Issue of report for GNEP PEIS
04/01/08	1	Incorporate changes to waste data and additional footprints for waste storage.
06/19/08	2	Revised Table 8 to include estimated volumes of fission products in off-gas (iodine, C-14, tritium, krypton, xenon, ruthenium) in HLW and reduced the corresponding volumes from LLW and GTCC. Revised the transportation numbers in Table 12 to reflect the off-gas waste being categorized as HLW.

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Acronyms

Acronym	Definition
Am	Americium
Ba	Barium
C	Carbon
CCD-PEG	Chlorinated Cobalt Dicarbollide/Polyethylene Glycol
CFR	Code of Federal Regulations
Ci	Curie
Cm	Curium
Co	Cobalt
Cs	Cesium
DOE	Department of Energy
DOT	Department of Transportation
ECF	Entry Control Facility
EPA	Environmental Protection Agency
FP	Fission products
GNEP	Global Nuclear Energy Partnership
GTCC	Greater-Than-Class C
GWh	Giga Watt hour
H-3	Tritium
He	Helium
HEPA	High Efficiency Particulate Air
HLW	High Level Waste
HVAC	Heating, Ventilation and Air Conditioning
I	Iodine
kw	Kilowatt
lb	Pound
LLW	Low Level Waste
Ln	Lathanide
LWR	Light Water Reactor
µCi	Microcurie
MPC	Multi Purpose Canister
MTHM	Metric Ton Heavy Metal
MVA	Million Volt Amps
MWh	Mega Watt hour
Nb	Niobium
nCi	NanoCurie
NEPA	National Environmental Policy Act
Ni	Nickel
Np	Neptunium

Acronym	Definition
NRC	Nuclear Regulatory Commission
PEIS	Programmatic Environmental Impact Statement
Pu	Plutonium
Rb	Rubidium
RCRA	Resource Conservation and Recovery Act
Ru	Ruthenium
scf	Standard Cubic Feet
SNF	Spent Nuclear Fuel
SNM	Special Nuclear Materials
Sr	Strontium
TALSPEAK	Trivalent Actinide Lanthanide Separations by Phosphorus-reagent Extraction from Aqueous Complexes
Tc	Technetium
TRU	Transuranic
TRUEX	Transuranic Extraction
U	Uranium
UDS	Un-dissolved Solids
UO_3	Uranium Trioxide
UREX	Uranium Extraction

1.0 Introduction

The Department of Energy's (DOE) Global Nuclear Energy Partnership (GNEP) is a comprehensive strategy to increase United States and global energy security, reduce the risk of nuclear proliferation, encourage clean energy development around the world, and improve the environment. GNEP recommends that the United States move from a once-through fuel cycle to a new approach that includes recycling of spent nuclear fuel (SNF) without separating the transuranic components of spent nuclear fuel. This capability would employ advanced technologies to recover and reuse fuel resources and reduce the amount of wastes requiring permanent geological disposal.

Under the GNEP recycling could accomplish:

- Separation of high purity uranium from the spent fuel that would allow recycle for re-enrichment or for other use or disposition
- Separation and immobilization of long-lived fission products, technetium, and iodine for disposal in a geological repository
- Extraction and decay storage of short-lived fission products (cesium and strontium) to meet the requirements for disposal
- Separation of transuranic (TRU) elements for fabrication into fuel for an advanced recycling reactor. The advanced recycling reactor is a fast reactor that would consume the transuranic elements and recover their energy.

The proposed nuclear fuel recycling center would separate the SNF from Light Water Reactors (LWRs) and advanced recycling reactors into its reusable components and waste components and manufacture new nuclear fuel using reusable components that still have the potential for use in nuclear power generation. The proposed nuclear fuel recycling center consists of the LWR SNF recycling facility, transmutation fuel fabrication facility, and the fast reactor SNF recycling facility. This report provides the National Environmental Policy Act (NEPA) information for a fast reactor SNF recycling facility. This facility is just part of the overall GNEP program.

The fast reactor SNF recycling facility is assumed to be co-located with the other nuclear fuel recycling center facilities at a Greenfield site in the United States. The goal of the facility would be to separate the potentially reusable constituents (uranium and transuranic elements) from the non-reusable constituents (e.g., fuel element structural materials and fission products) in the SNF discharged from advanced recycling reactors. The reusable constituents would be used to make transmutation fuel that would be returned to the advanced recycle reactor for re-use. Non-reusable constituents would be converted to waste forms for eventual disposal in a geologic repository or for other long-term storage or disposal, as appropriate.

2.0 Recycling Facility Operations and Requirements

The recycling facility will receive and manage fast reactor SNF, dissolve the fuel core from inside the cladding material, and use various solvent extraction steps to separate the various components of SNF. The best available engineering information for the NEPA Programmatic Environmental Impact Statement (PEIS) is presented in this report. Reasonable assumptions have been made for the purpose of developing the NEPA analysis data such that the construction requirements and operational characteristics would envelope all anticipated environmental impacts over the planned 40 year operation. The assumption has been made that the SNF from the advanced recycling reactors is a ceramic oxide and would be recycled using the UREX[1] separation processes. Electrorefining technologies are also a likely option for recycling fast reactor SNF and are discussed in this document. Electrorefining would also be the likely separation method if metallic fuels are used in the advanced recycling reactors. However, it is assumed at this time that aqueous separations recycling bounds the environmental impacts of alternative technologies (Reference 4).

Key facility operations for recycling of fast reactor SNF include:

- SNF receipt, storage and transfer
- SNF preparation and head-end treatment
- Processing and purification
- Product Handling - solidification, packaging, storage and shipping of uranium and U/TRU oxides
- Waste Processing and Handling– packaging, storage and preparation for shipment of wastes

Key process support systems include:

- Remote handling systems
- Process controls and data management systems
- Heating Ventilation and Air Conditioning (HVAC) systems
- Health physics
- Safeguards and security systems
- Material control and accountability
- Sampling and analysis systems

The facility will be co-located with the other nuclear fuel recycling facilities, therefore many of the utilities and infrastructure buildings and functions will be shared. The shared facilities are not discussed in detail in this document. Another option would be to locate a recycling facility at each of the reactors.

[1] UREX+1a is used as a baseline for this document, other the separations process could be used (Table 1).

However, the centralized facility may bound the environmental impacts of many smaller facilities.

The recycling facility operations are shown schematically in Figure 1.

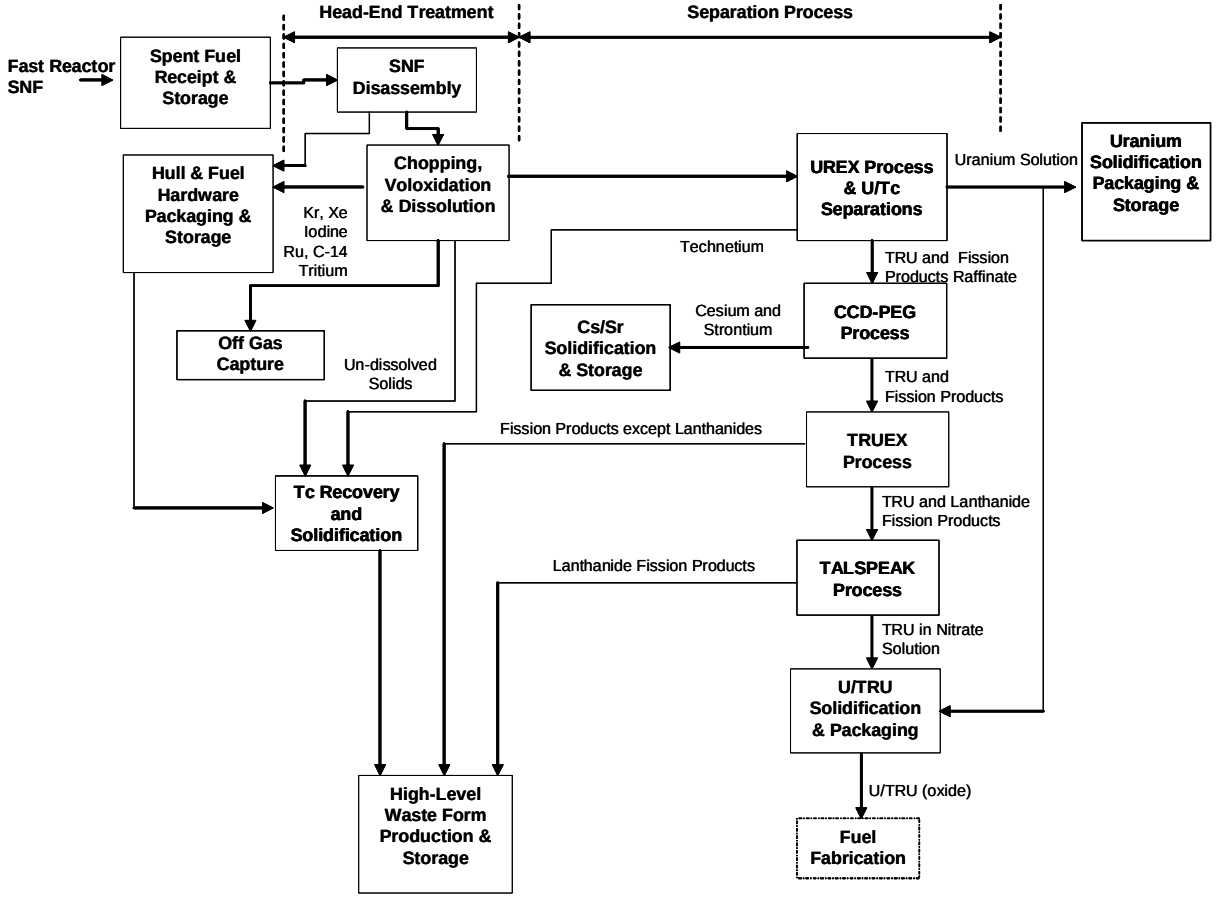


Figure 1 Recycling Facility Operations Diagram

For all potential recycling options, the SNF assemblies are received via truck or rail from a variety of off-site commercial nuclear facilities. These materials are stored pending preparation for separations processing. Fuel bundles are prepared for separations processing in the Head End process, where fuel rods are removed from the assemblies are then chopped into smaller pieces.

The recycling facility operations are shown schematically in Figure 2 for electrorefining.

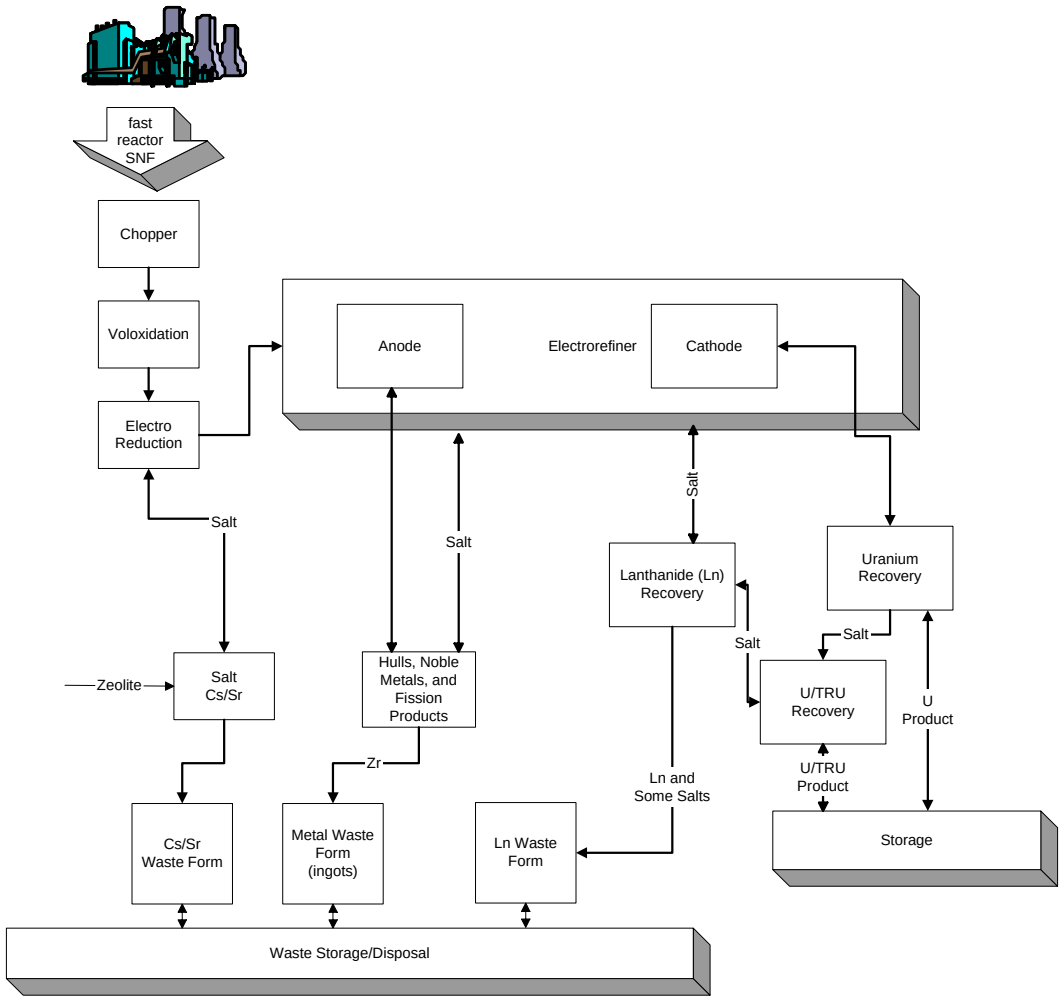


Figure 2 Electrorefining Diagram

In the UREX aqueous processes, the chopped fuel is voloxidized to remove the fuel, in the form of an oxide, from the cladding. The dissolved fuel is then fed to the separations process. In electrorefining, the oxide must be converted to a metal prior to the separations and purification steps. If metal fuel is being recycled, the fuel would be sent directly to the electrorefiner for separation.

The separations processes are designed to separate waste materials (fission products, rare earth elements, and other contaminants) from the actinide elements (uranium, neptunium, plutonium, americium, and curium) which are used in the fabrication of new fuels. Materials from the process to be used in fuel fabrication will be packaged in DOE certified containers for storage until shipped to the fuel fabrication facility.

The specifications for the advanced recycling reactor fuel have not been finalized. Therefore, modifications to the flowsheet chemistry and head-end process treatment systems are expected during the course of technology development for the future advanced recycling reactor fuels. There are various UREX processes that could be used to separate the fast reactor SNF. Table 1 provides a summary of the different UREX processes. Any one of these processes could be used in lieu of the UREX+1a described in this document. The environmental impact differences between the various processes should be minor.

Table 1 Suite of UREX+ Processes

Process	Prod.#1	Prod.#2	Prod.#3	Prod.#4	Prod.#5	Prod.#6	Prod.#7
UREX+1	U	Tc	Cs/Sr	TRU+Ln	FP		
UREX+1a	U	Tc	Cs/Sr	TRU	All FP		
UREX+2	U	Tc	Cs/Sr	Pu+Np	Am+Cm+Ln	FP	
UREX+2a	U	Tc	Cs/Sr	U+Pu+Np	Am+Cm+Ln	All FP	
UREX+3	U	Tc	Cs/Sr	Pu+Np	Am+Cm	All FP	
UREX+3a	U	Tc	Cs/Sr	U+Pu+Np	Am+Cm	All FP	
UREX+4	U	Tc	Cs/Sr	Pu+Np	Am	Cm	All FP

At each stage in the overall process, materials are analyzed for a variety of process parameters such as chemical and isotopic composition, particle size distribution, density, uniformity, and physical dimension. These analyses can be used for a variety of purposes such as quality assurance and process control, material control and accountability, and criticality safety. Evolved gases, and waste liquids and solids are also analyzed and treated to meet established Environmental Protection Agency (EPA) criteria. Some of these analyses are performed in-process, and some involve samples taken for analysis at a certified on-site or off-site analytical laboratory. Storage capacity is designed to ensure that throughput is not limited by materials availability.

Waste materials from the process areas are appropriately treated and packaged for storage, shipment and disposal as discussed in Section 3.0.

2.1 Operations Basis

The reasonable inventory of nuclear material contained in the various separations and storage processes is presented in Table 2 for the 100 metric tons of heavy metal (MTHM) per year facility. A 100 MTHM per year was assumed to meet the recycling needs for the future advanced recycling reactors producing up to 10 gigawatts of electricity per year. The mass basis is the initial heavy metal (i.e., actinide) content expressed as MTHM. The fission product content depends on the burn-up of fuel in the reactor (corresponding to power produced per unit mass of fuel) and on the decay products during cooling. The average calculated distribution of elements and isotopes in the anticipated fast reactor spent nuclear fuel to be received is presented in Appendix A.

The baseline process throughputs for 100 MTHM/year are calculated using a maximum 0.42 MTHM rate of ceramic oxide SNF per day, with the normal percentage of planned and unplanned outages. These process throughputs are used to develop baseline equipment designs and layouts, which, in turn, are used to develop a theoretical plan for the entire facility. At this early planning stage, there are many engineering details that have not been defined. However, the process throughputs used in this report are selected to bound all possible processing inventories that would reasonably be required to support such an operation.

The LWR SNF recycling facility is being used as a guide to determine the NEPA input data for the fast reactor SNF recycling facility. Work done in support of the advanced fuel cycle research facility was also used to develop this document since fast reactor SNF recycling is a component of its mission.

The fuel used in fast reactors is a combination of uranium and transuranics, therefore the SNF generated from fast reactors (also known as advanced recycling reactors) is different from LWR SNF. LWR SNF is comprised of approximately 87% uranium with the remaining being transuranics, fission products, and lanthanides. Fast reactor SNF has less uranium than LWR SNF due to its lower initial concentration of uranium. Depending on the fast reactor design and conversion ratio, the uranium content of fast reactor SNF will vary from 25% to 80%, with the remaining fraction being transuranics, fission products, and lanthanides. This NEPA report assumes that the fast reactor SNF (250 GWD/MTHM burnup, 1 year cooled) contains approximately 25% uranium. Using the 25% uranium, the transuranics make up approximately 49% of the SNF with the remaining being the fission products and lanthanides. These differences impact the product and waste flow rates and composition.

The radionuclides that would be removed as wastes, such as Cs/Sr, fission products and lanthanides, are 26% of the fast reactor SNF compared to 11% in LWR SNF. The percentage of fission products and lanthanides would decrease if the initial concentration of uranium was higher in the fast reactor fuel.

Table 2 Inventory of Nuclear Materials for Defining the Operations Basis

Facility Description		**100 MTHM/year Facility**
Process Area		**Annual Material Processing Throughput** 250 GWD/MTHM, 1 year cooled, fast reactor SNF
SNF Storage		• At the baseline rate of 100 MTHM/yr, the 2-year storage capacity equates to 2,400 fast reactor SNF assemblies. • Isolate and manage a minimum of 5% fuel assemblies received that may be damaged or otherwise unsuitable for near-term processing.
Operation Time		240 days per year (minimum)
Product Storage	UO_3	Store 1 years' production of UO_3
	U/TRU	Store 1 years' production of U/TRU
High Level Radioactive Waste Forms		On-site storage capacity for up to 1 years' production of high level waste (HLW) forms.
Cs/Sr Decay Storage		On-site decay storage for 1 years' production of separated Cs/Sr fission product wastes.

Notes: 1) HLW repository should be operations the time this recycling facility is constructed. 2) The transmutation fuel fabrication facility will be operational by the time this recycling facility is constructed.

2.2 Process Descriptions

Due to the intense radiation field exhibited by the spent fuel and the associated processing operations, all of extraction operations will be performed in shielded, remotely operated maintained environment (e.g., hot cell or canyon) utilizing manipulators and other alternative remote handling equipment. Viewing to support the remote operations will be provided via shielding windows, cameras, or some combination of the above.

2.2.1 SNF Receipt, Storage and Transfer

Spent nuclear fuel assemblies will arrive onsite via commercially licensed transport from the advanced recycling reactors. The transport vehicle will consist of a special railcar or special truck with casks specifically designed for the safe and secure transport of fast reactor SNF. All shipping casks will be United States Nuclear Regulatory Commission (NRC) licensed, and contents will be within license constraints. All fuel receipt, inspection, and transfer operations must be done remotely. This is due to high radiation levels associated with fuel assemblies.

The fuel transportation casks will be received and staged in a receipt area where contamination surveys and other integrity checks can be performed. The facility will have sufficient handling capability and storage for the relatively short cooled

fast reactor SNF. Once the casks are unloaded spent fuel casks will be transferred to storage with active cooling due to the high heat load of the relatively short cooled SNF. The SNF from advanced recycling reactors is higher in activity and decay heat generation than typical LWR fuel.

Capability to quarantine, repackage or delay processing of a limited amount of fuel will be provided as necessary to handle a leaking assembly or a bundle damaged during shipment or unloading. Inspected SNF fuel assemblies will be retrieved from storage and transferred to an area for subsequent processing.

The facility is assumed to be able to store 2 years throughput in the fuel storage areas. Fast reactor fuel is ordinarily cooled by sodium metal; however the sodium coolant will have been removed from the exterior of the fuel assemblies prior to shipment to the recycling facility.

2.2.2 Head End Treatment

SNF must be mechanically and remotely handled, disassembled, and chopped and de-clad prior to treatment in the separations processes. The generalized head end treatment processing is illustrated in Figure 2. SNF fuel assemblies will be remotely received for further processing in a shielded receipt and storage area. The fast reactor SNF assemblies will require some disassembly to remove the fuel rods from the duct prior to shearing. Depending on the reactor design, the individual fuel rods may be wrapped with a wire spacer that may need to be removed prior to shearing. The rods will then be fed to a shear operation where the internal pressure will be relieved. Provisions will be made to capture radioactive gasses as they are released from the rods to prevent spreading contamination beyond the initial control barrier or zone, and to control environmental gaseous releases.

The shear process will generate fuel rod segments 1 to 2 inches long. The fuel rods segments will then be transferred to a voloxidation[2] process. Voloxidation converts ceramic fuel to a powdery form more suitable for dissolution, while the fission product gases such as tritium, iodine, ruthenium and carbon-14 are released and are sequestered in the head end off-gas capture process. The rods also contain helium that will be released during shearing.

After voloxidation, fuel will be transferred to the dissolvers and reacted with nitric acid to dissolve the spent fuel oxides. The dissolver solution will be fed to the separation processes. The un-dissolved solids (UDS) remaining after secondary dissolution will be combined with the Tc alloy waste form and packaged for disposal at a geologic repository.

[2] The process for oxidizing irradiated fuel pellets to release the volatile fission products (iodine, xenon, C-14 as CO_2, krypton and tritium) from the pellets.

The spent fuel hulls and other remaining fuel assembly hardware (e.g., outer duct) will be further treated with nitric acid and supplemental washes as necessary to remove excess material that may not have been reacted with nitric acid during the normal dissolution cycle. The hulls and hardware for advanced recycling reactor fuels is stainless steel unlike the zirconium cladding used primarily for LWR fuel. After washing, the metal will be rinsed and dried. Parts of the fuel bundle removed prior to the dissolving operation (e.g. outer duct and wire), are prepared for disposition by use of acid washes and rinses as necessary. A portion of the metal will be transferred to Tc Solidification to be used in the alloying process. The remaining metal wastes from the fuel assemblies will be combined, compacted and packaged for storage and disposal. The metal waste will be remotely handled due to presence of highly radioactive activation products.

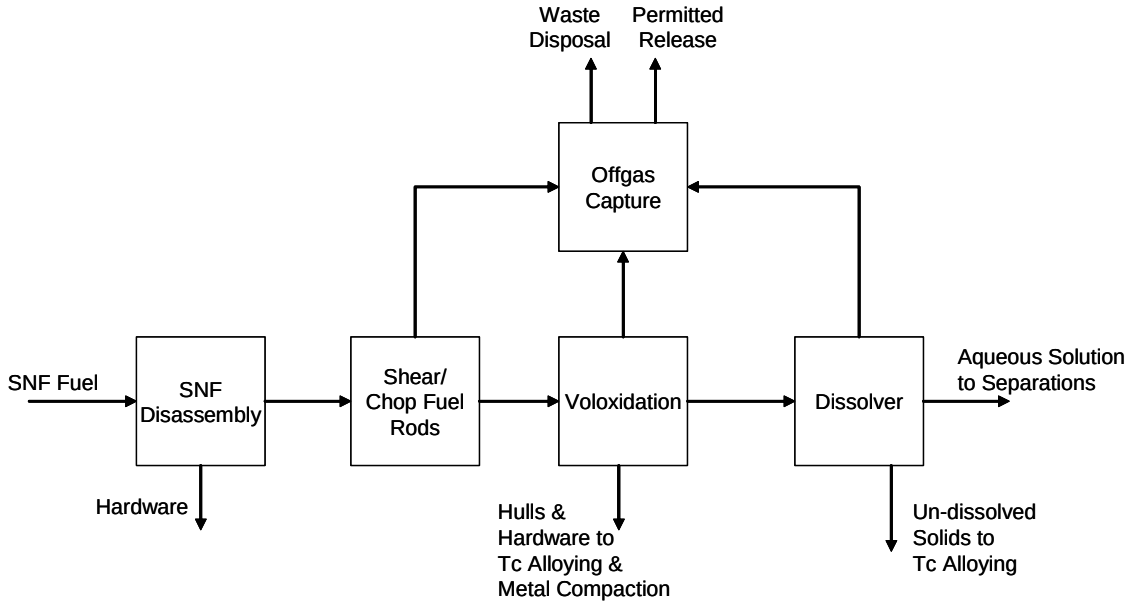


Figure 3 Generic Head End Processing Block Flow Diagram

One of the differences between aqueous processing of ceramic oxide fuels and metal fuels is the presence of sodium in the fuel pellets. The metal fuel has a sodium metal bonding filling the rod to cladding spaces that must be removed prior to dissolution. After chopping in an inert atmosphere, the metal fuel pieces are sent to a sodium removal oven. After sodium removal the pieces are sent to voloxidation. The sodium is solidified, collected and disposed of in accordance with Federal, State and local laws and regulations. It is possible that the solidified sodium can be recycled in the fabrication of metal fuel. The remaining sodium that adheres to the metals surfaces of the rod and hull pieces will be removed using steam in an inert atmosphere. Some of the sodium will be in the off-gas system where it will be treated appropriately.

2.2.3 SNF Separation Process

The UREX+1a separation process is a series of four solvent extraction (Figure 3) operations to separate products and waste. The separations are being performed to extract and purify uranium and transuranic products from the SNF, which will be blended use as a feed stock for advanced recycle reactor fuel. As part of this process the partitioned waste products will be treated and disposed of accordingly. The first solvent extraction (UREX) separates uranium and technetium from the dissolved spent nuclear fuel solutions (fission products, lanthanides, TRU elements), and from each other. The next extraction, CCD-PEG, which is named for the extractant used, separates cesium and strontium from the UREX raffinate[3]. The third extraction (TRUEX) separates the transuranics (TRU) and lanthanides from the other fission products. The final extraction operation, TALSPEAK, partitions the lanthanide fission products from the TRU elements.

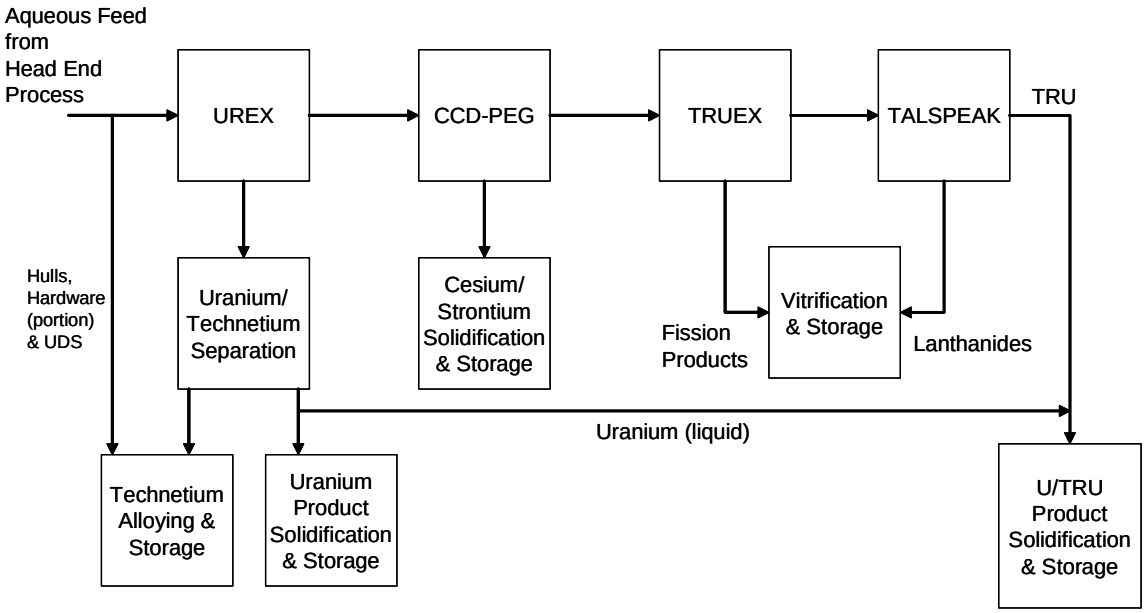


Figure 4 Generic Separations Processing Block Flow Diagram

The UREX separations process has several variations, UREX+1a is just one of them (Table 1). Another variation that is a potential for the separation of fast reactor SNF would have an additional step to separate out the Am and Cm from the TRU process stream. The Am and Cm could be used as targets and the remaining TRU products would be used for fuel fabrication.

[3] Raffinate is the aqueous stream that remains after the UREX extraction

2.2.3.1 Separations Process Products

There are two product streams generated by the UREX+1a separations process (Figure 3), a uranium oxide for potential future reuse and a transuranic (TRU) oxide material that will be used to fabricate fuel for the advanced recycling reactors. The individual product streams are concentrated and converted to oxides.

Uranium Solidification

After separation from technetium, a portion of the uranium solution is transferred to U/TRU oxide solidification for blending with the TRU product. The remaining uranium solution is converted to a solid (oxide) and packaged for storage and potential future reuse or disposal as low level waste. Off-gas will be passed through a cleanup system for emission control

U/TRU Oxide Solidification

Purified solutions of actinides (Pu, Np, Am, Cm) from the TALSPEAK process are combined with uranyl nitrate from the UREX process and converted to a stable oxide form and packaged for storage. Depending on fuel specifications the uranyl nitrate may not be combined with the TRU product until the fuel fabrication process.

The packaged material will be stored until shipped to a fuel fabrication facility for fabrication into fuel for an advanced recycling reactor.

2.2.3.2 Separations Waste Processing

There are three main waste streams generated from the UREX process (Figure 3). The streams are technetium (Tc), cesium/strontium (Cs/Sr) and fission products (including lanthanides). The baseline waste form for each stream is different and is discussed below.

Technetium Recovery and Immobilization

Technetium co-extracted with uranium is separated by an ion exchange process. The loaded ion exchange resin is then pyrolyzed to produce a metallic technetium product. The recovered metallic technetium is then alloyed with a portion of the fuel hulls and hardware and the UDS to produce a metallic waste form that will immobilize the technetium. This high level waste form will be packaged for on-site storage awaiting shipment to a geological repository for disposal.

Cs/Sr Solidification

The Cs/Sr solution from CCD-PEG is evaporated and subsequently solidified. The current baseline process is to stabilize the components with additives to produce a solid waste form. Active cooled storage may be required for several years. Upon sufficient decay to reduce radiation and thermal output the Cs/Sr solid waste form will be disposed of in an appropriate facility. Cs/Sr could also

be combined with the Fission Product/Lanthanide stream, if desired, and solidified into borosilicate glass.

Fission-Product/Lanthanide Solidification

The fission product waste streams from TRUEX and lanthanides from TALSPEAK separations processes must be treated to a solidified, leach-resistant waste form suitable for disposal in a high level waste geological repository. The final waste form is assumed to be borosilicate glass in a stainless steel waste package[4]. Storage and cooling of the solidified high-level waste (HLW) package will be required prior to shipment to the geologic repository.

2.2.4 Process Support for Separations

The fast reactor SNF recycling facility requires a wide range of process support functions. Process support includes but is not limited to off-gas handling, solvent recovery, and acid recovery. Although not discussed in detail in this section, another important process support function is the make-up of the chemicals needed in the separations process such as the solvent mixtures and various acids. Many of these chemicals will be brought onto the site in large quantities and stored until needed.

Off-Gas Handling

Off-gases (vents) from all process and chemical systems will undergo treatment incorporated into the ventilation system. The process must provide for defense-in-depth (i.e., multiple barriers and/or confinement zones to control releases as close as possible to the source). Volatile off-gas components such as iodine, krypton, helium, carbon-14, ruthenium, and tritium require treatment in order to meet emissions (permit) requirements. Recovered gases will be packaged for disposition.

Solvent Recovery

Spent solvent from solvent extraction operations is sequentially washed to remove radioisotopes and degradation products from the solvent. Washed solvent is re-circulated for process use. Spent solvent will be used in the reduction of NOx to NO. Solvent that cannot be reused or used elsewhere in the facility will be dispositioned per applicable regulatory requirements.

Acid Recovery

Evaporator overheads from all processes are collected for further treatment. Where possible, acid will be recovered and recycled. Recovered acid will be recycled for process makeup where feasible. Acid that cannot be reused will be sent to a co-located onsite industrial wastewater treatment facility for processing.

[4] This form represents a known approach to achieving a waste package that can be approved by Office of Civilian Radioactive Waste Management (OCRWM) for disposal in the high level waste repository with minimal impact.

2.2.5 Electrorefining

In electrorefining, after voloxidation, the spent fuel hulls are not separated from the oxide (Figure 5). Parts of the fuel bundle removed prior to voloxidation (e.g. end plates) are combined with other metal wastes, melted into ingots and packaged for storage and disposal. The metal waste will be remotely handled due to presence of highly radioactive activation products.

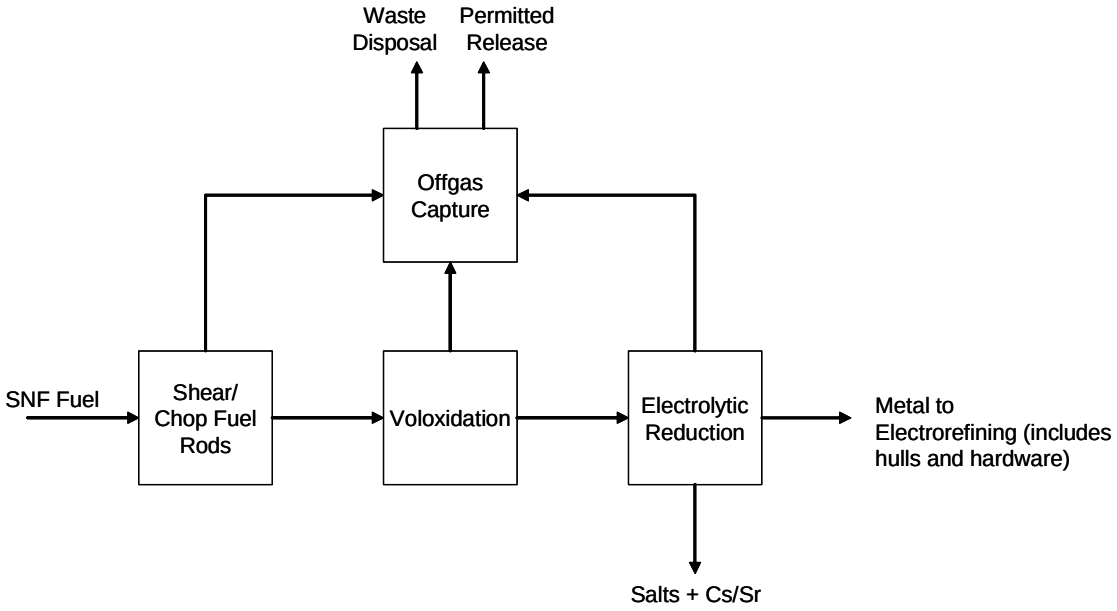


Figure 5 Generic Head End Processing Block Flow Diagram for Electrorefining

The oxide must be reduced to a metal so that the material can be separated and purified in the electrorefining process. This is done using electrolytic reduction in a molten salt electrolyte. Cesium (Cs), strontium (Sr), barium (Ba) and rubidium (Rb) form chlorides that are removed from the salt via ion exchange. The cleaned salt is reused. The zeolite containing the Cs, Sr, Ba, and Rb will be converted to a stable waste form and packaged for disposal.

The separation and recovery of uranium and TRU from SNF is completed in the electrorefining step. The metal product from the electroreduction process are transferred to a molten salt electrorefiner where a uranium metal product is collected on steel electrodes, and harvested along with entrained salt. The lanthanides and other fission products that do not partition into the electrolytic reduction salt will be converted to chlorides in the electrorefiner salt (Figure 6). The transition metals and hulls remain with the anode in the electrorefiner. The recovered hulls, noble metals, and fission products from the anode are melted into metal ingots for storage and disposal.

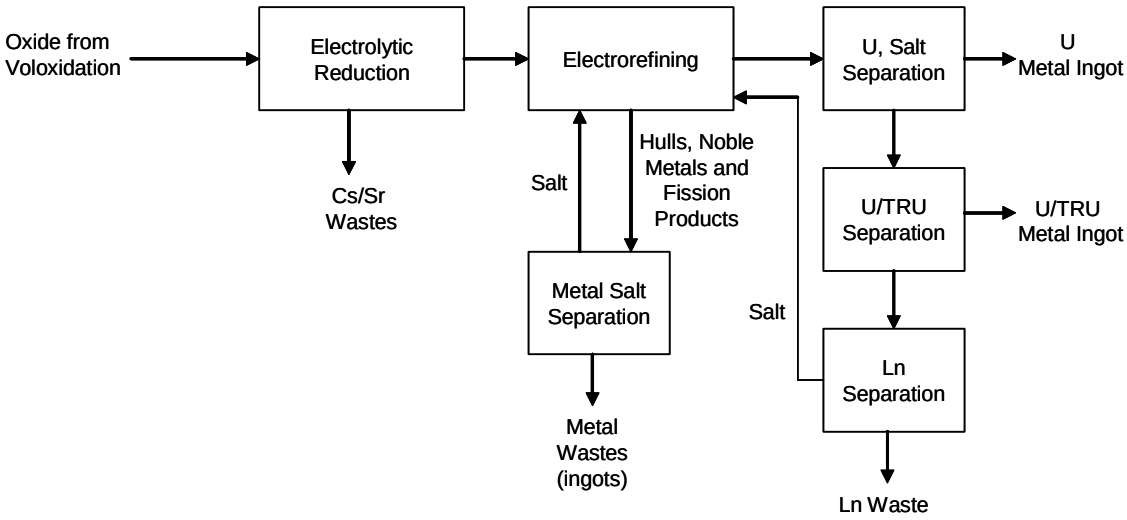


Figure 6 Electrorefining Block Flow Diagram for Oxide Fuel

The uranium and salt mixture is processed to separate the salt and produce a uranium metal ingot. The salt is further processed to first remove the TRU elements creating a U/TRU metal ingot and second to remove the lanthanides (Ln). The salts are recycled back to the electrorefiner and the Ln waste is converted to a glass for disposal. The process is shown in Figure 6.

There are two products and three waste streams generated from electrorefining of fast reactor SNF. The two products are a uranium metal and a U/TRU metal. These metals can be converted to oxide and stored or kept in metal form.

The three waste streams are Cs/Sr, metal, and Ln wastes. The Cs/Sr combined with the zeolite will be converted to a glass-like form and stored until it has sufficiently decayed for disposal. The metal wastes will be converted to ingots and packaged for on-site storage awaiting shipment to a geological repository for disposal. The lanthanides will be solidified in a glass matrix, packaged, and stored on-site awaiting shipment to geologic repository.

Voloxidation and oxide reduction would not be necessary for metallic fuel. (Figure 7).

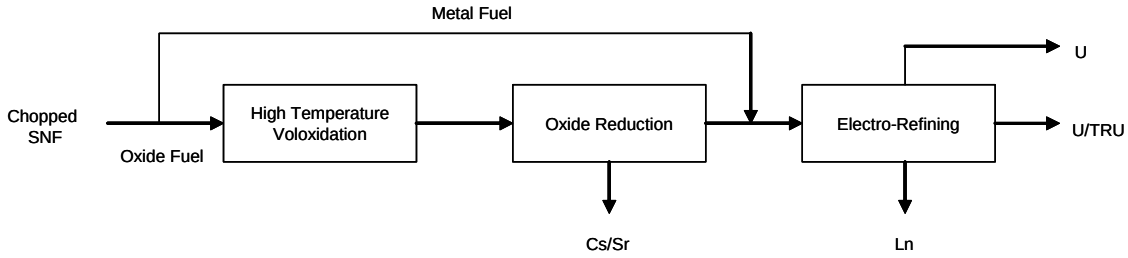


Figure 7 Generic Electrorefining Block Flow Diagram

2.2.6 Waste Management

Waste products will be generated at every step of the separations process operations. Generated wastes will be managed in accordance with applicable Federal, state and local laws, regulations and requirements. A preliminary disposal pathway has been developed for each anticipated waste stream from the recycling facility. Since the time frame to begin construction and operation of the recycling facility is greater than 10 years, there may be other treatment and/or disposal options available for any of the wastes described in this report.

The wastes generated from the recycling facility will be categorized as either low-level waste (LLW), mixed LLW, Greater-Than-Class C (GTCC) wastes, HLW, hazardous waste or non-hazardous waste. The categorization will depend on the radioisotopes present in the waste form, relative concentrations, and in some cases source of the waste regardless of concentration. A brief description of LLW, GTCC and HLW has been provided below. A variety of radioactive waste processing techniques are planned and waste disposal pathways are identified as shown in Figure 8. The disposal pathways outlined in Figure 8 are based on current laws, policies and regulations. It is possible for a disposition pathway to be changed, if in the future a law, policy or regulation is changed.

It is the generator's responsibility to properly characterize the waste stream prior to disposition. In general, a generator's characterization approach for each waste stream will consider:

- its source
- its use prior to being declared a waste
- its predominant radionuclide content and distribution
- its physical properties and chemical constituents
- the type of disposal container used
- the feasibility of quantifying a package's radioisotope or chemical content directly or indirectly using emitted radiation

All waste forms will meet applicable waste acceptance criteria for the waste

treatment or disposal facility prior to leaving the facility. The primary wastes include activated metals (fuel rod hulls and assembly hardware), sorbed gaseous fission products (tritium, krypton, xenon, ruthenium, iodine and carbon-14), solidified fission products, and solidified processing liquids.

Low level liquid radioactive waste is assumed to be treated at a co-located onsite permitted wastewater treatment facility that is associated with the LWR SNF recycling facility. The facility will discharge to a permitted outfall. All emissions will meet regulatory (permit) limits. All wastes generated within the wastewater facility will be managed accordingly. Solvents and other similar organics are anticipated to be shipped for offsite treatment and disposal. Information regarding the LWR SNF recycling facility can be founding in the *Engineering Alternative Studies for Separations NEPA Data Input Report*, EAS-Q-NEP-G-00001, Revision 0 (Reference 1).

Hazardous wastes will be treated to immobilize or destroy the hazardous component which can be accomplished onsite or off-site. All hazardous wastes will be treated, managed and stored in accordance with RCRA regulations and shipped to RCRA permitted facilities for treatment, storage, and/or disposal.

Proven technology has been applied as a baseline for all waste treatment processes. No credit was taken for emerging technology improvements. The fast reactor SNF recycling facility will consider waste minimization and pollution prevention to minimize facility and equipment contamination and to make future decontamination and decommissioning as simple and economical as possible.

2.2.6.1 Low Level Waste Description

LLW are wastes containing source, special nuclear, or byproduct material that are acceptable for disposal in a shallow land disposal facility as opposed to a deep geologic repository. For the purposes of this definition, low-level waste has the same meaning as in the Low-Level Waste Policy Act (PL 95–573, December 22, 1980) that is, radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act (AEA) (PL 83-703, August 30, 1954) or naturally occurring radioactive material.

Low level radioactive wastes can be in the form of solids, liquids, or gases. Low level radioactive waste is also classified based upon the concentration and type of radionuclides involved (10 CFR Part 61). LLW are classified in accordance with 10 CFR 61.55.

Wastes that have nuclide concentrations greater than values listed in 10 CFR 61.55 are generally not acceptable for near surface disposal. These wastes are also low level waste but for the purposes of this report are considered as a separate category called GTCC wastes, which is discussed in Section 2.2.5.2.

Low-level wastes include both Resource Conservation Recovery Act (RCRA) (also known as mixed wastes) and non-RCRA regulated radioactive wastes, these waste will be disposed of at a NRC licensed LLW disposal facility. Mixed wastes may be treated prior to disposal to destroy or immobilized the hazardous component. The residue from the treatment process will be appropriately packaged and disposed of in accordance with applicable regulations. Liquid waste streams containing radioactive materials will be treated (i.e., solidified) and classified according to the appropriate DOE or NRC waste regulations. Some liquid waste streams may be sent to the co-located industrial wastewater facility for treatment. Solid LLW from process operations, such as equipment, general operations/maintenance waste, and job control waste will be packaged for disposal in accordance with existing regulatory guidelines.

2.2.6.2 Greater Than Class C Waste Description

Greater Than Class C waste is radioactive waste generated by licensees of the NRC that exceeds the concentration limits of radionuclides established for Class C waste [see Section 2.1 and 10 CFR 61.55(a)(2)]. Because of the relatively high concentration of long-lived radionuclides (e.g., C-14, Ni-59, Tc-99) in GTCC waste, GTCC waste is unsuitable for near-surface disposal. 10 CFR 61.55(a)(2)(iv) requires GTCC waste to be disposed of in a geologic repository as defined in 10 CFR 60 or 10 CFR 63 unless a proposal for disposal in a near surface disposal facility is approved by the NRC. Disposal in a near surface land disposal site requires a performance assessment to be prepared and approved by the NRC for the waste form and disposal location (typically on a case-by-case basis). Because GTCC waste is unlikely to be routinely disposed of at a near-surface land disposal site regulated per 10 CFR Part 61, the GTCC waste must be stored until it can be disposed of at a licensed geologic repository.

GTCC waste which will be produced at a recycling facility can be segregated into two categories. The first category would be GTCC waste due to activated metals. The second category is due to other isotopes such as cesium-137, strontium-90, iodine-129, technetium-99, carbon-14 and transuranics (atomic number greater than 92). GTCC can also be mixed with RCRA hazardous waste, which will make disposal a little more complex.

In accordance with the Low-Level Radioactive Waste Policy Act, the DOE is responsible for disposal of waste exceeding limits established for Class C radioactive waste as defined by 10 CFR 61.55; however, disposal of GTCC waste generated by a NRC licensee is to be disposed of in a facility licensed by the NRC. In short, DOE[5] is responsible for the siting, constructing, operating and maintaining a GTCC disposal facility and NRC will be the licensing authority. The NRC issued a final rule requiring the disposal of GTCC low-level radioactive

[5] DOE has issued an Advance Notice of Intent to Prepare an Environmental Impact Statement for the Disposal of Greater-Than-Class C Low-Level Radioactive Waste, Federal Register 70(90), May 11, 2005, pp. 24775-24778.

waste in a geologic repository, unless disposal has been approved elsewhere (*54 FR 22578*, codified at 10 CFR Part 61). Although the NRC has indicated that the disposal of GTCC waste in near-surface disposal facilities is generally not acceptable, the requirements of 10 CFR Part 61 would be applicable to the disposal of commercially generated GTCC waste in "intermediate" disposal facilities. The exception to the definition allows NRC to authorize such waste to be disposed without necessarily invoking the additional requirements of 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes".

2.2.6.3 High Level Waste Description

In the *Nuclear Waste Policy Act of 1982*, as amended, the term high-level radioactive waste is defined as: "(a) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (b) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation."

Irradiated or spent nuclear fuel is used fuel from a reactor that is no longer efficient in creating electricity, because its fission process has slowed. However, it is still thermally hot, highly radioactive, and potentially harmful. Until a permanent repository for spent nuclear fuel is built, licensees must safely store this fuel at their reactors or other locations licensed for storage. Recycling extracts isotopes from spent fuel that can be used again as reactor fuel. The waste from recycling is highly radioactive and contains fission products and other highly radioactive material, in sufficient concentrations, that is determined, consistent with existing law, to require permanent isolation.

The identification of high-level waste is considered relatively straightforward since it is primarily linked to the source from which it was derived, i.e., it is the highly radioactive material resulting from the reprocessing of spent nuclear fuel. Background and knowledge of both the *Nuclear Waste Policy Act of 1982* definition, as amended, and the NRC definition, in 10 CFR Part 60, is needed to ensure that waste that is to be managed as high-level waste has been properly

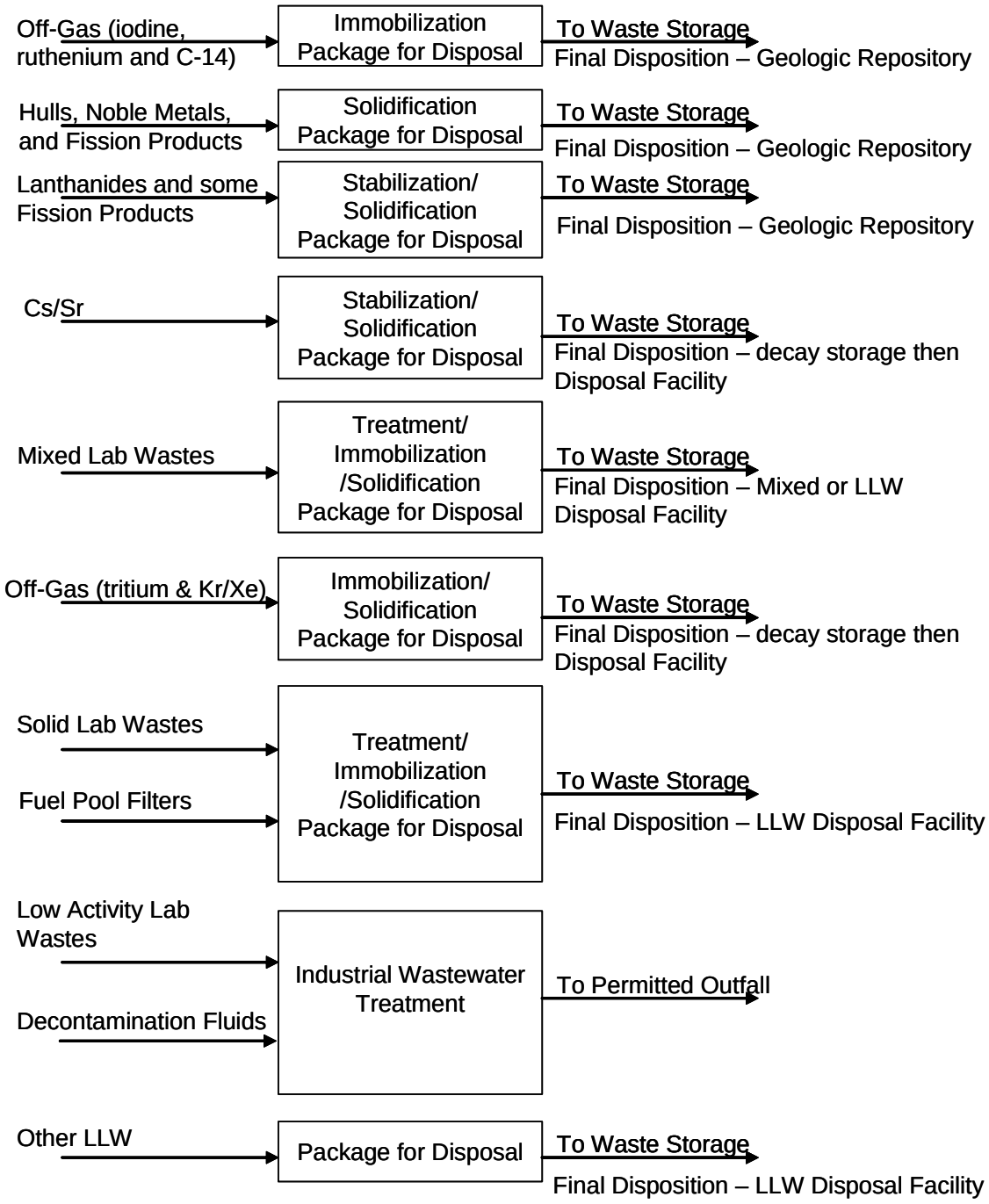


Figure 8 Schematic Block Flow Diagram for Radioactive Waste Management

characterized. Wastes that are produced upstream of the separations processes, from such processes as chemical or mechanical de-cladding, fuel dissolution, cladding separations, conditioning, or accountability measuring, are not high-level waste. Such wastes are considered processing wastes and should be managed as either GTCC, mixed low-level, or low-level waste.

2.2.7 Analytical Laboratory

Fully-equipped analytical laboratories are provided to enable rapid chemical, isotopic, and physical property analyses required to support process control, accountability, criticality safety, and waste management needs. Wastes from analytical laboratories will be appropriately segregated, characterized, and incorporated into recycle or waste streams. It is anticipated that the fast reactor SNF recycling facility will have its own laboratory; however some support may be provided by a large central laboratory associated with the co-located facilities.

2.3 Facility Requirements

The recycling facility includes process buildings and support buildings as shown schematically in Figure 9. The total site area within a property protection fence is on the order of 250 acres.

The site is anticipated to have, at a minimum, the following buildings, support structures and features:

- Main Process Buildings
- Administrative Buildings
- Truck Loading Docks
- Analytical Support
- Fire Protection Facility and Tanks
- Entry Control Facilities (ECFs)
- Cooling Towers
- Electrical Power Substations
- Emergency/Standby Diesel Generator Buildings
- Chillers, Chemical Feed and Chilled Water Pump Buildings
- Nitrogen/Argon Storage Tanks
- Chemical Storage Tanks
- Spare Equipment Laydown Yard
- HVAC Exhaust Stacks
- Waste Handling Facilities
- Commodities Warehouse
- Roads and Parking Areas
- Runoff Detention Basins
- Railroad Tracks

2.3.1 Security

It is anticipated that the main process facilities would be located within an enhanced security area to protect the nuclear material from diversion or sabotage. Entry control facilities at the entrance to the security protection areas would allow security personnel to inspect all vehicles and all personnel entering and leaving the fast reactor SNF recycling facility. Physical security would be provided by armed guards.

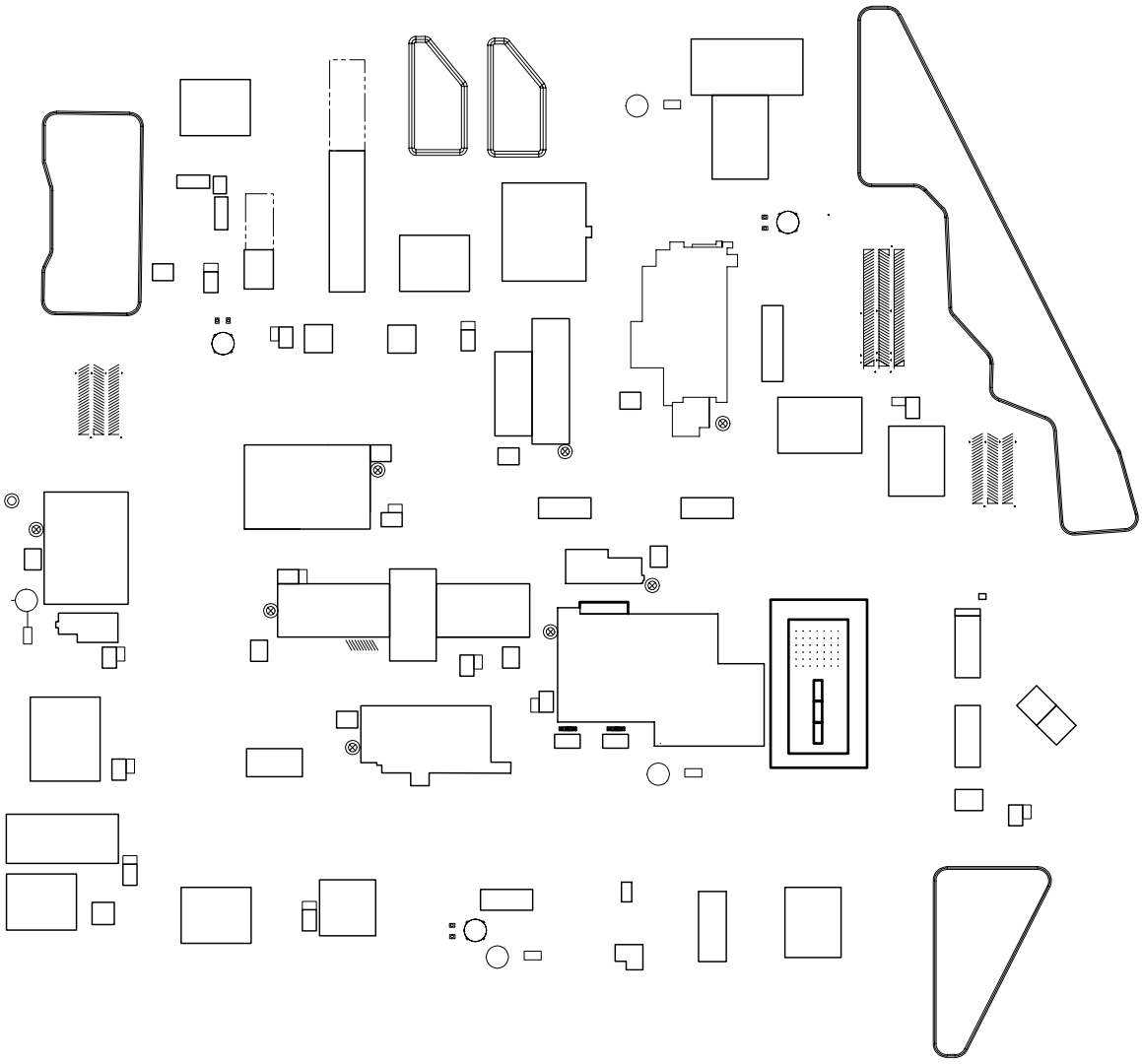
2.3.2 Process Buildings

The proposed concept would place most of the processes into as few buildings a possible. The major process functions are:

- receiving and storing SNF and head-end preparation of SNF;
- processing, recovering, and purifying aqueous spent nuclear fuel;
- separation, solidification and storing of uranium and technetium;
- solidification and storing of U/TRU product;
- solidification and storing of fission products; and
- solidification and storing of Cs/Sr wastes.

All of these process functions require shielding provided by hot cells and/or canyons. The proposed process areas could be separated into different buildings or contained within a single, large building. The process buildings would generally be multi-storied, reinforced concrete structures, with hot cell facilities below grade and equipment handling above grade. The process buildings are hardened to meet safety and security requirements. Containment, confinement, shielding and criticality control measures will be integrated in the facility design and layout to provide personnel protection and environmental protection from exposure to radioactive and hazardous substances.

The footprint for the processing areas is estimated to be on the order of 520,250 ft^2 for the 100 MTHM facility. The process area footprint provides space for processing area support functions including mechanical, electrical, and process control equipment, analytical laboratory spaces; cold storage; and access corridors. In the current concept, the shielded areas are placed below grade (to depths approaching 40 feet), and the overhead cranes and other support equipment required for unloading and moving shipping casks and processing equipment extend to heights averaging 70 feet above grade. Some buildings may require building heights greater than 70 feet above grade. The process areas also include various tunnels for the transfer of materials between buildings.



Note: Not to Scale

Figure 9 Conceptual Recycling Facility Layout

Construction estimates (concrete, aggregate, water, structural steel, etc.) presented in this report are based on this bounding footprint and other facilities with similar features and missions. Table 3 provides the footprint area discussed above. The footprint does not include shared infrastructure, only building directly associated with the fast reactor SNF recycling facility.

Table 3 Building Size Details

	Area (ft^2)
	100 MTHM/year Facility
Total Area of Main Processing Buildings	624,300
Total Support Building Area	608,128
Total Building Area	1,232,428

The current footprint for the Fast Reactor SNF Recycling Facility assumes only one year of storage for each of the types of waste. To account for the potential for additional storage capacity, the footprint for the Fast Reactor SNF Recycling Facility would need to be increased by the following values depending on waste stream. It is expected, however, that a disposal pathway for these wastes will be available while the facility is operating. If so, additional storage capacity would not be required. A phased construction plan with expandable capacity is envisioned to handle this waste and provide sufficient but not excess storage capacity. New capacity would be built every five to ten years to accommodate a portion of the total waste that would be generated during the subsequent years of production. The need for the construction of new storage space would be reduced or eliminated when disposal paths for the various waste categories are decided.

- 2,690 ft^2/yr Cs/Sr wastes
- 3,130 ft^2/yr HLWs including Hulls and Hardware*
- 9,400 ft^2/yr for GTCC wastes (not including Hulls and Hardware storage)
- 71,000 ft^2/yr for LLWs (includes any grouted wastes)
- 1,660 ft^2/yr for combination of Hazardous Wastes and Mixed Waste

* Hulls and Hardware are GTCC waste but due to the need for remote handling they are assumed be placed in the same storage facility as the HLW to reduce the need for two storage facilities with remote handling capabilities.

UREX+1a aqueous separations process is one of several separations processes that can be utilized for fast reactor SNF. If another method of separations was chosen, the size of the facility and layout of the facility could change.

2.3.3 Support Buildings

The major support buildings and structures include, but not limited to, one or more utility/mechanical buildings, storage areas for rail- or trailer-mounted shipping casks, one or more exhaust stacks, one or more fan houses, and reagent storage areas. Other support buildings and structures include a temporary concrete batch plant, temporary construction support facilities, and temporary construction laydown areas that would be required only during the construction phase. Permanent structures include, but are not limited to, waste handling facilities (LLW, mixed waste, and hazardous waste), analytical laboratory, administration buildings, bulk chemical storage, a warehouse, personnel access points, electrical substations, stormwater retention areas, and parking areas. The total footprint of support structures is estimated to be 608,128 ft^2 for the 100 MTHM/year facility (Table 3). This footprint for the support structures does not include buildings shared within the nuclear fuel recycling center. The shared buildings are accounted for in the footprint for the LWR SNF recycling facility (Reference 1).

2.3.4 Construction Requirements and Impacts

The construction of the 100 MTHM/year facility is estimated to occur over a 8 year period. Construction materials, utilities and wastes are summarized in Tables 4 and 5. The construction materials are estimated based on a similar facility with the same footprint and function to recycle fuel (i.e., proposed LWR SNF recycling facility). Fuel requirements are primarily based on estimates of the machinery and operating requirements for excavation of the processing building areas and do not include other site preparation (e.g. grading). For the purpose of estimating the air quality impact of construction, it should be assumed at a minimum that the entire site maximum area of 250 acres disturbed by grading or other site preparation activities. Water requirements include water for dust suppression, concrete production, and washdown. Aggregate volume does not include the aggregate used in concrete; it is only aggregate used for other purposes such as road base. The concrete estimate includes the aggregate used for the making of concrete. Structural steel includes reinforced steel embedded in concrete in addition to all other structural steel required.

Table 4 Construction Requirements

Material / Resources	Consumption/ Use 100 MTHM/year Facility
Peak Electrical Energy (Million Volt Amps (MVA))	
Total	46
Peak Yearly	43
Diesel Generators	Yes - Portable
Number of horsepower-hours of diesel-fueled engines (bulldozers, dump trucks, diesel generators, etc) during the peak year of construction	859,4386
Number of delivery vehicles during peak year of construction	19,600
Concrete (yd^3)	
Total	924,000
Peak Yearly	112,800
Structural Backfill (yd^3)	
Total	3,584,000
Peak Yearly	1,120,000
Aggregate (yd^3)	
Total	560,000
Peak Yearly	168,000
Structural Steel (tons)	
Total	168,000
Peak Yearly	28,000
Liquid fuel and lube oil (gal)	
Total	8,869,000
Peak Yearly	1,176,000
Gases (m^3) – i.e. welding gases, etc.	
Total	512,960
Peak Yearly	69,195
Water (gal)	
Total	37,240,000
Peak Yearly	5,880,000
Number of Temporary Concrete Batch Plants	1
Temporary Concrete Batch Plant Area (acres)	32
Parking Areas (acres)	38
Post Construction Developed Area (acres)	250
Employment During Construction	
Construction period (years)	8
Total Employment (worker years)	29,221
Peak employment (workers)	7,676

Table 5 Construction Wastes

Waste Generated During Construction	Volume 100 MTHM/year Facility
Hazardous	
Liquid (gal)	26,460
Solid (yd^3)	67
Nonhazardous (Sanitary)	
Liquid (gal)	287,630
Solid (yd^3)	92,610
Nonhazardous	
Liquid (gal)	1,764,000
Debris from Site Clearing	10,780 tons
Excavated Material	3,136,000 yd^3
Metal Scrap	22,050 tons
Dunnage	3,920 yd^3

2.3.5 Operations Materials and Wastes

During normal operations, the fast reactor SNF recycling facility will process SNF to produce uranium and transuranic products and waste materials. Estimated throughputs and inventories of these processing materials, shown in Table 6, are based on the conceptual process flow sheets for similar facilities that are currently under development. Estimates of the operations data are provided in Table 7. Estimates of all the operations wastes, including process wastes, are provided in Table 7 to the extent available. Additional information on parameters for Operations is provided in Section 3.0.

Table 6 Estimates of Fuel Processing Materials and Wastes from Operations 100 MTHM/year Facility

Feed/Product/ Waste	Daily Rate (kg/day)	Annual Rate (kg)	Annual Bulk Container Rate	Maximum Storage Duration (years)
Transmutation SNF (assemblies)	929	222,912	1,200 assemblies	2
U Solidification and Storage Product	125	29,952	75	1
TRU Solidification and Storage Product	233	55,872	3,910	1
Fuel Hardware and Hulls Waste	291	69,696	20	1
Tc Metal Alloy Waste Form	154	36,864	11	1
Cs/Sr Waste Form	103	24,768	1,343	1
FP/Lanthanide Vitrified Waste Form	1,726	414,144	143	1

Table 7 Summary of Operations Data

Data Required	Consumption/Use 100 MTHM/year Facility
Electrical Consumption – daily and annual	2.4 GWh 725 GWh
Peak electrical demand (MVA) – daily	156
Diesel Fuel usage (gal) –annual	97,400
Other Process Gas (N, Ar, etc) – daily and annual	3,751 scf 900,352 scf
Domestic Water (gal) – daily and annual	108,000 32,616,000
Process Water (gal) – daily and annual	96,000 28,992,000
Cooling Tower Makeup (gal) – daily and annual	199,680 47,923,200
Steam (gal) – daily and annual	276,480 66,355,200
Employment (total workers)	2,000
Number of Radiological Workers	856
Average annual dose to Radiological workers (mrem)	250
Maximum annual Radiological worker dose (mrem)	1000

Sanitary wastes from the fuel fabrication would be treated at the co-located sanitary wastewater facility. In addition, any low activity aqueous wastes, such as liquids from the laboratories, would be treated at the co-located industrial wastewater treatment facility. The effluents from each of the wastewater facilities would be discharged to permitted outfalls. Wastes from the machine and maintenance shops would be the same as wastes from similar commercial facilities, and these wastes would be handled in a manner equivalent to these commercial facilities. Other non-hazardous wastes generated at the site include office and cafeteria wastes which will be packaged for disposal at commercial landfills.

Radioactive wastes from operations will generally fall into three categories: HLW, LLW and GTCC wastes as mentioned in Section 2.2.5. HLW results from reprocessing (also known as recycling) spent nuclear fuel[6] as discussed in Section 2.2.5.3.

Estimates of radioactive waste are based on the LWR SNF recycling facility (Reference 1). The radioactive wastes generated at the facility are tentatively classified as HLW, LLW or GTCC categories based on the expected half-lives or curie content and currently laws, policies and regulations. The results are shown in Tables 8.

[6] HLW is defined in Nuclear Waste Policy Act of 1982

Table 8 Estimates of Wastes from Operations

Waste Category	Volume 100 MTHM/year Facility	
	Daily	**Annual**
Low Level		
Liquid (L)	1.42	340
Solid (m^3)	20.9	5010
Mixed Low-level		
Solid (m^3)	0.21	50
Greater Than Class C (GTCC)		
Solid (m^3)	3.64	874
Mixed Solid (m^3)	0.05	10
HLW		
Solid (m^3)	1.11	267
Hazardous		
Liquid (L)	0.37	88
Solid (m^3)	0.17	40
Nonhazardous		
Liquid (L)	610,000	223,000,000*
Solid (m^3)	47.2	17,200*

* Waste volumes are based on 365 days per year since facility will be staffed year round and nonhazardous waste generation is based more on number of personnel and facility occupation than number of processing days.

Operation of fuel cycle facilities generates several different types of waste. Some are closely related to the process and throughput (e.g. fission products, used solvents, product packages and containers, and excess acid). Other waste streams (secondary wastes) are more closely related to staffing (e.g. sanitary waste) or plant systems and facilities (filters, laboratory wastes, decontamination material). However, the largest source of secondary radioactive waste is typically associated with routine operation and maintenance of the nuclear facilities and equipment. For NEPA purposes, estimates of total waste were derived by combining "process-related" wastes directly related to throughput, with estimates of secondary waste made for each facility. Estimates of secondary wastes considered process conditions, personnel activities (entries into contamination areas and protective clothing requirements), and forecasts of equipment failures, repairs, and replacement. Detailed estimates considering forecasts of routine operations and both major and minor maintenance activities were prepared for each case. Since the total quantity of waste for any given case is impacted by all of these factors, and their relative contribution varies with the type of operation and source materials, comparisons between cases are unlikely to be directly proportional to throughput except for process wastes. Detailed estimating methodology and facility specific assumptions are described in the *Waste Generation Forecast and Characterization Study - 800 MT/year UREX+1a* (Reference 3).

It is expected that any mixed (hazardous and radioactive) waste containing a hazardous component would be treated to remove the hazardous component either onsite or offsite. If performed onsite, such treatment would require a RCRA Part B permit to ensure that the hazardous components are treated and the waste is no longer considered RCRA hazardous or acceptable for land disposal per RCRA.

Storage of radioactive wastes would be designed to accommodate shielding, security, heat loading, inventory, storage duration, and other requirements. Packaging of radioactive wastes will be in accordance with applicable DOE, NRC, and/or Department of Transportation (DOT) regulations.

3.0 Summary of Wastes, Effluents, and Reagents during Operations

This section provides a summary of the wastes, effluents, reagent, emissions, etc. that are generated and/or used during operation of a fast reactor SNF recycling facility. A summary of nuclear materials and products is provided in Table 6. A summary of the wastes from fast reactor SNF recycling is provided in Table 8. There are two sources of liquid effluents from the recycling facility, the annual flow rates are shown in Table 9.

Air emissions from the various operations are shown in Table 10. The radioactive emissions alluded to in Table 10 are from head end processes which includes tritium, C-14, I-129, and Ru-106, and Cs-137 and Ru-106 can be released from the fission products vitrification process. The reagents used in fuel fabrication are shown in Table 11.

Table 9 Liquid Effluents from Operations

Effluent	Source	Annual Flow Rate (L) 100 MTHM/year Facility
Process wastes		No net flow of process liquid wastes
Liquid Effluent from Industrial Wastewater Treatment Facility*	Cleaning, evaporator condensate, etc.	10,220,610
Liquid Effluent from Sanitary Wastewater Treatment Facility		525,112,300

* It is anticipated that a portion of this effluent stream will be recycled back to the process to be used as process water.

Table 10 Air Emissions from Recycling Processes

Emissions	100 MTHM/year Facility	
	Daily (kg/day)	Annual (kg)
Nitrogen Oxides (NOx)	18.6	4,470
Hydrochloric Acid	0.34	81.2
Hydrofluoric Acid	1.50E-10	3.60E-08
Carbon Monoxide (CO)	28,371	6,808,896
Carbon Dioxide (CO_2)	92,094	22,102,560
Sodium Hydroxide (NaOH)	0.01	2.71
Sulfur Oxide (SOx)	78	18,720
Volatile Organics (contributes to Ozone)		<40
Radionuclides	<10 mrem per year	

Table 11 Reagents Used in Operations

Reagent
Nitric Acid
Tributyl phosphate
Acetohydroxamic acid (AHA)
n-dodecane
Chlorinated cobalt dicarbollide (CCD) in FS-13
polyethylene glycol (PEG-400)
Phenyltrifluoromethyl Sulfone (FS-13)
Diethylenetramine pentaacetic acid (DTPA)
Guanidinium carbonate
Octyl-(phenyl)-N,N'-diisobutylcarbamoylmethylphosphein oxide (CMPO)
Oxalic acid
Lactic acid
Hydrofluoric Acid
Bis-(2-ethylhexyl)phosphoric acid (HDEHP)
Sodium Carbonate Na_2CO_3
Ceric Acid
Ammonium carbonate
Compressed argon
Compressed nitrogen
Compressed propane
Hydrogen peroxide
Sodium hydroxide
Lithium nitrate
Sucrose, white granulated
Alkali Borosilicate Glass Frit
Reilex Resin

3.1 Transportation

The maximum throughput of the fast reactor SNF recycling facility is 100 MTHM of spent fast reactor fuel. The number of shipments per year depends on how many assemblies are in each shipment. Due to the final fuel form being a mixed oxide of uranium, plutonium, neptunium, americium, and curium and emitting gamma radiation, the transportation cask for the fast reactor SNF will require shielding similar to transmutation fuel. There is only one NRC-certified shipping cask, NLI-1/2, for transporting transmutation fuel per JAI 2005 (Reference 2). The NLI-1/2 is manufactured by NAC International and can hold one or two assemblies depending on their size. Assuming that the cask will hold only one assembly, the facility would make a maximum of 1,200 shipments per year.

The radioactive waste streams generated will require transportation offsite for treatment and/or disposal. The radioactive waste will go to licensed facilities in accordance with Federal, State and local regulations. Table 12 shows the anticipated transportation data for the three types of radioactive wastes discussed in the previous section. The number of shipments per year depends on how many containers are in each shipment. The shipping container for the

LLW is assumed to be a B-25 container that can hold up to 90 cubic feet of waste; however the containers are typically only filled to approximately 90% capacity. A 15 foot HLW canister is assumed for the HLW shipments and a 10 foot HLW canister for the GTCC wastes. It is assumed that the 10 foot HLW canister for the GTCC waste will be the most conservative for determining shipping impacts. The annual quantities provided in Table 8 were used depending on the waste form. The Cs/Sr waste was not included in the HLW shipment numbers since it will be placed into decay storage.

Table 12 Transportation Data for the Shipment of Wastes for 100 MTHM/year Facility

	LLW Annual	HLW Annual	GTCC Annual
Shipments of Wastes	184	39	246
Packaging Description	Type A or Type B containers	HLW canisters	HLW canisters
Mass per Container	5,000 lbs	2900 kg	3600 kg
Number of Containers per Vehicle	12	5	5
Origin and Destination	To licensed LLW or MLLW treatment or disposal facility	To licensed geological repository	To licensed geological repository
Physical Description of Container Contents	LLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	HLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	GTCC wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)
Chemical/Radiological Composition of Container Contents	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.

4.0 References

1. Washington Savannah River Company, “Engineering Alternative Studies for Separations NEPA Data Input Report”, EAS-Q-NEP-G-00001, Revision 0, March 2007
2. JAI Corporation, “Shipping and Storage Cask Data for Commercial Spent Nuclear Fuel”, JAI-582, March 2005
3. Washington Savannah River Company,, “Waste Generation Forecast and Characterization Study - 800 MT/year UREX+1a,” WH-G-ESR-G-00051, Revision 0, December 2007
4. Washington Savannah River Company,, “Environmental Impacts of Aqueous and Electrochemical Process Alternatives,” EAS-G-ESR-G-00064, March 2008

Appendix A – Activity of ABR Fuel (250 GWD/MTIHM, 1+ year cooled)

Isotope	Ci/MTIHM	Isotope	Ci/MTIHM
Activation Products		**Actinides and Daughters (continued)**	
H3	1.440E+00	Tl209	2.295E-07
Be10	9.388E-05	Pb209	1.063E-05
C14	2.898E+00	Pb210	4.251E-05
Ar39	4.077E-16	Pb211	6.229E-06
K42	2.741E-16	Pb212	1.341E-03
Ca45	2.440E-05	Pb214	1.332E-04
Ca47	4.546E-28	Bi210m	3.247E-18
Sc46	8.302E-09	Bi210	4.252E-05
Sc47	1.740E-27	Bi211	6.229E-06
Cr51	3.459E+01	Bi212	1.341E-03
Mn54	9.894E+05	Bi213	1.063E-05
Fe55	1.729E+05	Bi214	1.332E-04
Fe59	5.986E+01	Po210	4.252E-05
Co58	6.834E+03	Po211	1.744E-08
Co60	1.250E+03	Po212	8.590E-04
Ni59	1.781E+00	Po213	1.040E-05
Ni63	2.540E+02	Po214	1.331E-04
Zn65	8.574E-06	Po215	6.229E-06
Sr89	2.166E-04	Po216	1.341E-03
Sr90	4.896E-05	Po218	1.332E-04
Y90	4.897E-05	At217	1.063E-05
Y91	6.911E-05	Rn218	3.623E-13
Zr93	5.959E-04	Rn219	6.229E-06
Zr95	1.418E+00	Rn220	1.341E-03
Nb93m	5.273E-04	Rn222	1.332E-04
Nb94	5.487E-02	Fr221	1.063E-05
Nb95	3.158E+00	Fr223	8.589E-08
Nb95m	1.052E-02	Ra222	3.623E-13
Mo93	2.492E+00	Ra223	6.229E-06
Tc98	3.340E-06	Ra224	1.341E-03
Tc99	9.330E-01	Ra225	1.063E-05
Ru103	1.075E+00	Ra226	1.332E-04
Ru106	1.516E-07	Ra228	6.662E-11
Rh102	2.142E-04	Ac225	1.063E-05
Rh106	1.516E-07	Ac227	6.224E-06
Pd107	6.538E-12	Ac228	6.662E-11
Ag106	1.104E-29	Th226	3.623E-13
Ag108	9.899E-19	Th227	6.143E-06
Ag108m	1.112E-17	Th228	1.341E-03
Ag109m	3.949E-16	Th229	1.063E-05
Ag110	1.278E-13	Th230	1.637E-02
Ag110m	9.612E-12	Th231	1.162E-03
Ag111	3.721E-28	Th232	9.163E-11
Cd109	3.949E-16	Th234	8.397E-02
Actinides and Daughters		Pa231	8.134E-06
		Pa233	1.554E+01
Tl206	3.234E-18	Pa234m	8.397E-02
Tl207	6.212E-06	Pa234	1.092E-04
Tl208	4.817E-04	U230	3.619E-13

Isotope	Ci/MTIHM	Isotope	Ci/MTIHM
Actinides and Daughters (continued)		**Actinides and Daughters (continued)**	
U231	1.141E-31	Es254m	0.000E+00
U232	1.311E-03	Es254	6.932E-11
U233	3.680E-03	**Fission Products**	
U234	6.220E+01		
U235	1.162E-03	H3	4.329E+03
U236	6.255E-02	Be10	2.135E-05
U237	8.565E+01	C14	8.607E-04
U238	8.393E-02	Kr81	4.390E-06
U240	2.735E-06	Kr85	3.527E+04
Np237	1.554E+01	Rb86	4.580E-02
Np238	6.666E+01	Rb87	8.513E-05
Np239	3.500E+03	Sr89	1.013E+04
Np240m	2.735E-06	Sr90	2.405E+05
Pu236	5.472E-03	Y90	2.405E+05
Pu237	9.032E+00	Y91	2.806E+04
Pu238	4.685E+05	Zr93	9.033E+00
Pu239	9.263E+03	Nb93m	8.011E+00
Pu240	3.554E+04	Nb94	3.283E-03
Pu241	3.491E+06	Zr95	7.780E+04
Pu242	2.288E+02	Nb95	1.690E+05
Pu243	3.990E-04	Nb95m	5.771E+02
Pu244	2.739E-06	Tc98	3.812E-04
Pu246	7.211E-13	Tc99	9.783E+01
Am241	1.722E+05	Rh102	1.175E+02
Am242m	1.333E+04	Ru103	9.872E+03
Am242	1.327E+04	Rh103m	8.900E+03
Am243	3.500E+03	Ru106	2.054E+06
Am245	1.490E-05	Rh106	2.054E+06
Am246	7.212E-13	Ag106	1.457E-17
Cm241	3.692E-03	Pd107	1.911E+00
Cm242	7.842E+05	Ag108	7.259E-05
Cm243	4.053E+03	Ag108m	8.156E-04
Cm244	7.794E+05	Ag109m	2.364E+00
Cm245	3.309E+02	Cd109	2.364E+00
Cm246	4.539E+01	Ag110	2.757E+02
Cm247	3.990E-04	Ag110m	2.073E+04
Cm248	5.711E-04	Ag111	7.454E-10
Cm249	1.857E-15	Cd113m	8.695E+02
Cm250	2.832E-12	In114	2.555E-01
Bk249	1.027E+00	In114m	2.670E-01
Bk250	6.975E-11	Cd115m	3.265E+01
Cf249	9.556E-03	In115	4.507E-10
Cf250	9.093E-03	In115m	2.295E-03
Cf251	2.744E-06	Sn117m	5.565E-06
Cf252	9.135E-06	Sn119m	4.995E+02
Cf253	5.975E-13	Sn121m	7.894E+00
Cf254	6.311E-12	Sn123	2.686E+03
Es253	2.504E-11	Te123	1.059E-10

Isotope	Ci/MTIHM	Isotope	Ci/MTIHM
Fission Products (continued)		**Fission Products (continued)**	
Te123m	1.197E+01	La140	1.335E-02
Sb124	1.279E+02	Ce141	1.985E+03
Sn125	1.967E-07	Pr143	3.323E-02
Sb125	9.861E+04	Ce144	1.332E+06
Te125m	2.403E+04	Pr144	1.332E+06
Sn126	9.955E+00	Pr144m	1.598E+04
Sb126	1.394E+00	Pm146	1.694E+02
Sb126m	9.955E+00	Sm146	3.336E-05
Sb127	1.286E-23	Nd147	2.225E-04
Te127	6.439E+03	Pm147	8.552E+05
Te127m	6.574E+03	Sm147	5.508E-05
Xe127	4.820E-03	Pm148	5.401E+01
Te129	6.145E+01	Pm148m	9.589E+02
Te129m	9.440E+01	Sm151	2.597E+04
I129	3.206E-01	Eu152	8.103E+02
Xe129m	3.599E-13	Gd152	7.354E-11
I131	7.297E-08	Gd153	5.561E+02
Xe131m	6.717E-05	Eu154	3.931E+04
Cs132	1.263E-14	Eu155	8.778E+04
Xe133	7.866E-15	Eu156	1.438E-02
Cs134	4.316E+05	Tb160	5.317E+02
Cs135	1.187E+01	Tb161	1.511E-12
Cs136	1.105E-03	Ho166m	3.023E-02
Cs137	7.241E+05	Er169	2.644E-12
Ba137m	6.850E+05	Tm170	3.452E-02
La138	2.954E-10	Tm171	1.308E-03
Ba140	1.160E-02		